Image Reconstruction for the Solar Gravity Lens

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Research Summary

Contemporary methods of direct imaging for exoplanets have yielded the first images of their kind, though none have yet allowed humanity to view the surface of an alien world. Resolving the fine structure of objects as small and distant as planets orbiting other stars requires a telescope the proportions of which are not capable with current technology, with a diameter on the order of ten kilometers. While humanity cannot fabricate a telescope of this size on our own, there exists a point just fifty billion miles away where we can focus light thats been gravitationally lensed around the Sun, effectively turning a well-placed and modestly-sized one-meter telescope into a forty-kilometer telescope. This concept is known as the Solar Gravity Lens, or SGL.

A major caveat of the SGL is that a gravitational lens, like the Sun, does not produce one coherent image like a typical telescope; rather, depending on the alignment of the target, lens and observer, it produces distorted images of the target around the outside of the lens. When the three are in perfect alignment, or in syzygy, we observe a ring around the outside of the lens, known as an Einstein ring this is the form that pictures from the SGL will take.The question of how the original image of the exoplanet can be extracted from this warped ring of light is completely open, and that is exactly what we hope to help answer with our research.

Specifically, we want to show that this sort of reconstruction is possible for gravitationally lensed images, showing that we can manipulate simulated data to indirectly yield the image the simulation was fed. Our hypothesis for how to go about this comes in two parts: (a) simulating the gravitationally lensed images as seen by the SGL, and (b) feeding those simulated images into a pipeline which trains itself to reconstruct the original images.

The simulation will yield physically accurate lensing data, for which we will write a fully general relativistic raytracing code, providing point-for-point accurate photon mapping of the SGL for images we supply to it. The pipeline will consist of a neural network which will take a large number of these simulated images as input, train itself to recognize patterns in their similar distortions and use these consistencies to recreate the images fed to the simulation.

In creating our simulation and pipeline, we hope to provide a proof-of-concept for the process of syzygal reconstruction, as the pristine alignment conditions for strong lensing that the SGL will possess have never been observed naturally and, thus, have not been studied extensively. The literature on lens reconstruction is focused on galaxies and mass-mapping, leaving the reconstruction of fine structure an unexplored arena. While our methods will likely be somewhat lacking in the rigor necessary to process real astronomical data, we hope that this work will lay the foundation for a more thorough treatment of the reconstruction pipeline.

The SGL is capable of resolving a great many objects in unparalleled detail, but much emphasis in the literature and in proposals has been placed on observing exoplanets which have been deemed potentially habitable. There exist potential life-harboring habitats in our own solar system, like Mars and Europa, but extraterrestrial life has not been directly observed anywhere in our universe thus far. With the magnifying power of the Solar Gravity Lens, we can accurately identify biochemical signatures in the atmospheres of these planets and, even more directly, see flora, fauna and non-natural structures on the surfaces of these planets if they exist there. The SGL is capable of allowing humanity to answer a question that has long plagued the minds of us all: Are we alone?